initiating their approaches to compliance. CALFED plans to develop a close working relationship with utilities producing drinking water from the Delta in order to coordinate planning efforts and take maximum advantage of the opportunity to combine source water improvements with improved treatment plant operations. A greater understanding of these plans would allow prioritization of CALFED Water Quality Program actions and perhaps development of other helpful actions. Information gathering should continue during refinement of the proposed actions and as part of the CALFED Phase III implementation.

3. Evaluation of approaches to reduce organic carbon loadings to the Delta from agriculture.

   A number of potential methods can reduce organic carbon loading to Delta waterways. These methods have been discussed, and some have received preliminary evaluation. However, no method has been adequately studied to assess the actual reduction in loading, the feasibility, or the costs. Pilot studies at Rock Slough and Old River should be undertaken to determine the water quality efficacy of relocating agricultural drains from Veale Tract away from the Rock Slough intake. An existing drainage management program for Byron Tract appears promising and is supported by CALFED. In addition, development and use of Delta flow models to specifically assist with this evaluation is recommended. Contra Costa Water District (CCWD) has been involved in ongoing efforts to model water quality at intakes. Continuing efforts of The Metropolitan Water District of Southern California (MWD), California Urban Water Agencies (CUWA), DWR, and USGS to use models in order to estimate water quality at the intakes should be supported and extended by CALFED.

   An existing drainage management program for Byron Tract appears promising and is supported by CALFED.

4. Augmentation of existing monitoring activities as needed to determine drainage volumes and quality in Delta channels.

   Currently, data on drainage volume discharges to Delta channels are based on older studies and limited recent data. Additional measurements of irrigation return flow and irrigation return quality are needed.

5. Assistance in identifying and developing improved analytical techniques for *Cryptosporidium* and *Giardia*.

   Significant limitations in current measuring techniques create uncertainty in the use of the data.

6. Evaluation of algae and macrophyte growth constituents.

   Algae and macrophyte growth constituents and their origins should be evaluated, and methods should be devised to reduce algae and macrophyte production in conveyance and storage facilities of drinking water diversions from the Bay-Delta. CALFED should support research actions addressing: (1) the relationship between nutrient levels and excessive algae and macrophyte growth problems in water supply facilities; and (2) the role and importance of other factors, such as water facility operation, in producing algae blooms. This research activity should be coordinated with DWR, the U.S. Bureau of Reclamation (Reclamation), and water supply agencies involved in the operation and maintenance of water supply facilities containing Delta water supplies. Such research would provide: (1) information that is necessary for the identification of feasible source control actions, and (2) MPs to address the problem of excessive algae and macrophyte growth in water supply facilities.

Existing Activities

The State Water Contractor's Sanitary Survey Action Committee (SSAC) meets regularly in an ongoing effort to investigate and correct water quality problems identified by the two previous sanitary surveys of the SWP that were published in 1990 and 1996. Sanitary surveys are repeated every 5 years, and efforts to protect the quality of SWP waters are ongoing.

In addition to DWR's Municipal Water Quality Investigation (MWQI) Program, other agencies are undertaking studies to evaluate some of the measures being considered by CALFED. CALFED should help support these studies to the extent warranted.

In addition to DWR's Municipal Water Quality Investigation Program, other agencies are undertaking studies to evaluate some of the measures being considered by CALFED.

Treating Agricultural Drainage

The MWQI Program commissioned a preliminary study to assess the feasibility of treating agricultural drainage in order to improve organic carbon concentrations in Delta waterways. The study found that up to a 60% reduction in TOC concentrations could be achieved with conventional ferric chloride coagulation-flocculation. Whether drainage treatment can be cost effective and feasible has not been determined. The following activities should be included in a comprehensive study of agricultural drainage management.

Managing Frequency of Leaching

Most Delta islands with peat soils are leached every 3 years. If the islands were leached only during years when Sacramento River and San Joaquin River flows

were high, the high flows potentially could flush the leachate out of the system. By not leaching in low-flow years, organic carbon concentrations potentially could be reduced in the south Delta. However, the implications of not leaching could affect the productivity of Delta islands. A stakeholder process should be initiated with Delta agricultural interests to determine the need for, and to direct, additional studies. From such a process, a BMP approach might be developed and implemented.

Rerouting Agricultural Drainage

Rerouting several key agricultural drains potentially could improve export water quality.

Rerouting several key agricultural drains potentially could improve export water quality. For example, CALFED and other stakeholders believe that rerouting or otherwise managing agricultural drainage on Veale Tract and Byron Tract away from Rock Slough could provide lower TOC concentrations at the CCWD pumping plant on Rock Slough. Brown and Caldwell evaluated the feasibility of collecting Delta agricultural drainage and discharging it past Chipps Island. That study indicated that over 700,000 acre-feet of drainage, with a peak flow of 1,600 cfs, discharges annually from various locations in the Delta. Pilot studies at Rock Slough and Old River should be undertaken to determine the water quality efficacy of relocating drains. In addition, the development and use of Delta flow models are recommended to specifically assist with this effort. Ongoing efforts of MWD, CUWA, DWR, and USGS to use models in order to estimate water quality at the intakes should be supported and extended by CALFED.

Storage in Detention Ponds with Release during High Flows

Reducing agricultural drainage at times when pumping rates are high also could improve export water quality.

Potentially, agricultural drainage could be stored in detention ponds and released during periods of high flow when it would have less impact on Delta water quality. Reducing agricultural drainage at times when pumping rates are high also could improve export water quality. While such operations could improve the quality of diverted drinking water sources, it would not improve south Delta water quality. Real-time monitoring of various water quality parameters, including organic carbon, could be used to determine optimum times for release of stored drainage water. However, there are concerns that storing water in detention ponds may actually increase the organic carbon concentra-tion of the drainage, and drainage detention ponds would certainly occupy valuable acreage. Further study is warranted.

Converting to Low-Tillage Cropping and Other Options

Some water quality scientists believe that converting from agricultural crops that require extensive tillage and irrigation to low-tillage cropping and other options, such as permanent pasture and grazing, could reduce soil oxidation and the loading of organic carbon discharged from Delta islands. The efficacy of these MPs on drinking water source impacts needs to be further studied.

Converting to Flooded Wetlands

In addition to the benefits described above for changing land use practices on agricultural lands with peat soils, maintaining saturated soil conditions may further reduce oxidation and therefore organic carbon loading. Pilot studies on flooded lands need to be conducted to determine whether flooding offers useful land management options and whether such activities would result in adverse water quality consequences.

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Implementing Irrigation Efficiency Measures

Flooding to leach salt and some irrigation methods (e.g., spud ditch irrigation) are extremely inefficient with respect to irrigation and salt management, and produce large volumes of drainage water and large loads of TOC. Implementation of water-conserving irrigation and salt management methods may offer significantly decreased drainage water volumes and TOC loads. Studies need to be conducted in order to evaluate the potential of irrigation efficiency measures to reduce TOC and salt loads in drinking water sources.

3.6.2 Sacramento and American Rivers

Priority Actions

1. Evaluate the effects of increased urbanization and recommend control strategies.

   It is generally recognized that water quality is currently higher in the Sacramento and American Rivers than in the Delta proper. However, long-term urban development is expected along these rivers that could potentially degrade their quality. CALFED recommends study of the potential impacts of increased urbanization over the next 30 or more years on wastewater and stormwater loadings to the Sacramento and American Rivers. Where appropriate, mitigation measures would be developed and implemented.

It is generally recognized that water quality is currently higher in the Sacramento and American Rivers than in the Delta proper. However, long-term urban development is expected along these rivers that could potentially degrade their quality.

2. Control algal blooms in upstream reservoirs and aquatic weed growth in the lower American River.

   This is a water treatment issue for the City of Sacramento's Fairbairn Water Treatment Plant to reduce nutrient loadings that support algal and aquatic weed growth. Impacts on the water supply from aquatic plant growth include T&O, as well as clogging of fish screens. Additional studies are required specific to this source to determine why this problem occurs and potential solutions.

3. Reduce impacts from livestock grazing along the Sacramento River by the use of BMPs.

Livestock grazing, dairy operations, and other confined animal feeding operations are potential sources of pathogens, TOC, nutrients, and TDS in the Sacramento River watershed. The City of Sacramento, Department of Utilities has been tracking research concerning grazing animals and their potential contribution of pathogens to the Sacramento River system, as well as the implementation of grazing BMPs in the Sacramento River watershed. The University of California, Davis, (UC Davis) Extension Program has conducted extensive research on various grazing animals, with the cooperation of the grazing industry. The Cattlemen's Association has been supporting research on BMPs for grazing lands, as well as promoting these practices in its educational outreach programs. The UC Davis Extension Program provides educational resources and rangeland water quality short courses for the grazing industry. CALFED should assess the findings of these independent programs and support stakeholder involvement and implementation of livestock management BMPs. Efforts would be generally useful to several watersheds that affect drinking water intakes in the Delta. Implementation of prevention measures, such as buffer strips along stream channels, offer the prospect of ecosystem enhancement opportunities and should be coordinated to achieve maximum benefits. CALFED should support BMP development and enforcement by the RWQCBs of pollution prevention measures.

Livestock grazing, dairy operations, and other confined animal feeding operations are potential sources of pathogens, TOC, nutrients, and TDS in the Sacramento River watershed.

4. Reduce impacts for dairies and other confined animal feeding operations.

Confined animal feeding operations may contribute pollution to the Delta through poor management of animal wastes. The CVRWQCB has identified more than 1,600 dairies in the region, and spot inspections have indicated that many of the facilities are following practices that may adversely affect water quality.

Information Needed

1. Determine the impacts from the Natomas East Main Drain.

DWR has collected data at this location, but it was noted that a data gap remains with respect to understanding loadings and impacts from the Natomas East Main Drain. Because of interest in rerouting agricultural drains and relocating drinking water intakes in the northern parts of the Delta, it would be useful to determine the water quality effects of this drain.

2. Determine the sources of contaminants of concern to the watershed.

Previous studies have shown that information on the sources of organic carbon in the Sacramento River watershed is incomplete. The Sacramento River Watershed Program (SRWP) will collect some data on organic carbon concentrations at a number of locations along the Sacramento River and its major tributaries. Data are needed on the concentrations and loads of organic carbon in urban runoff, wastewater discharges, and agricultural drainage. CALFED should support and augment the SRWP effort as needed.

Previous studies have shown that information on the sources of organic carbon in the Sacramento River watershed is incomplete.

Information also is needed on the key sources of TDS in the Sacramento River watershed. As the population of the watershed grows, potential mitigation measures may be needed for increased wastewater and urban runoff discharges with high TDS. DWR authored a paper about TDS impacts resulting from anticipated population growth in the watershed. The CMARP should consider expanding on the study to evaluate key point sources of TDS in the watershed.

Information also is needed on the key sources of TDS in the Sacramento River watershed.

3. Estimate the likely future impacts from increased urbanization.

As noted above, future development may adversely affect water quality in the Sacramento and American River watersheds. An estimate of adverse impacts is recommended.

Existing Activities

Wild animals may be a source of pathogens to the Sacramento and American Rivers and to the Delta in general. UC Davis is planning to conduct research on this potential source of pathogens. Of particular interest is information on loading of protozoan pathogens such as *Giardia* and *Cryptosporidium*. CALFED should support these activities.

Wild animals may be a source of pathogens to the Sacramento and American Rivers and to the Delta in general.

3.6.3 North Bay Aqueduct

Priority Actions

1. Implement the Barker Slough Watershed Management Program.

Solano County Water Agency (SCWA) and the other North Bay Aqueduct (NBA) water users are in the process of developing a management program to control drinking water contaminants in the Barker Slough watershed. The tasks include identifying areas with the greatest impact on source water quality and designing BMPs with the potential to improve the quality of

SCWA and the other NBA water users are in the process of developing a management program to control drinking water contaminants in the Barker Slough watershed.

runoff water and the quality of water in Barker Slough at the pumping plant. The most suitable BMPs, including structural and non-structural, will be implemented by property owners on a voluntary basis. Water quality monitoring will ascertain the effectiveness of the BMPs. A watershed stakeholders group has been formed to advise the NBA contractors on all aspects of the program.

SCWA has received a $580,000 Delta Tributary Watershed Program grant to evaluate BMPs and develop the watershed management plan. Additional funding will be needed to fully implement the plan. CALFED will support implementation of a watershed management plan and will provide funding to implement BMPs that will improve watershed runoff water quality and to provide water quality monitoring in the Barker Slough watershed.

2. Study the feasibility of relocating the NBA intake.

The water quality in the NBA is considered some of the poorest in the Delta for drinking water (with respect to TOC and turbidity, but not with regard to bromide), resulting largely from water quality degradation in the watershed. Future changes in the northwest Delta may degrade the water quality at Lindsey Slough, which appears to provide an element of dilution to the degradation from the upper watershed. Large CALFED environmental restoration projects near the mouth of Lindsey Slough may cause an increase in organic carbon levels and potentially an increase in pathogen levels. In addition, the goal of these restoration projects is to increase populations of the fish species of concern. Increases in these fish populations may lead to restrictions in pumping at the Barker Slough Pumping Plant.

The water quality in the NBA is considered some of the poorest in the Delta for drinking water (with respect to TOC and turbidity, but not with regard to bromide), resulting largely from water quality degradation in the watershed.

An alternative under consideration is construction of an alternate point of intake either on the Tehama-Colusa Canal or on Miner Slough. These alternate intakes would provide the option to use source water containing a larger proportion of Sacramento River water, which is often of considerably higher quality in terms of organic carbon and turbidity, compared to Barker Slough. An in-depth analysis of the need for, and feasibility of, constructing an alternate intake is recommended. Potential water quality impacts of the ecosystem restoration activities, specifically at Lindsey Slough, need to be studied to determine whether the activities will increase concentrations of organic carbon or other drinking water contaminants at the NBA intake. Determining that these activities cause negative water quality impacts would provide further impetus for constructing an alternate point of intake for the NBA.

Potential water quality impacts of the ecosystem restoration activities, specifically at Lindsey Slough, need to be studied to determine whether the activities will increase concentrations of organic carbon or other drinking water contaminants at the NBA intake.

Information Needed

1. Conduct studies to further delineate the dry season organic carbon contributions and possible means to reduce loads.

   Laboratory and field studies are needed to determine sources of organic carbon and other drinking water contaminants at the Barker Slough Pumping Plant. Studies should address the in-channel contribution of algae and other aquatic plants, and the sources of organic carbon in the watershed.

2. Collect water quality data for alternative intake locations.

   Water quality data are needed at potential alternative intake locations (currently, the Tehama-Colusa Canal and Miner Slough).

3. Study the water quality impacts of CALFED ecosystem restoration activities on Barker Slough Pumping Plant diversions.

   Study the water quality impacts of CALFED ecosystem restoration activities on Barker Slough Pumping Plant diversions and identify mitigation strategies, as needed.

Existing Activities

1. Development of the Barker Slough Watershed Management Plan.

   CALFED will support the development of the Barker Slough Watershed Management Plan by the NBA contractors with partial funding by the Delta Tributary Watershed Program.

3.6.4 South Bay Aqueduct

Priority Actions

1. Implement a watershed management program within the South Bay Aqueduct (SBA) proper.

   The SBA is open from Bethany Reservoir to near Lake Del Valle. Although the size of the contributing watershed is small, sanitary surveys have identified specific problems resulting from ranching and other watershed activities that could allow agricultural and stormwater runoff into the SBA and contribute to algal growth. A study should be conducted to determine the

areal extent of watershed that contributes to the SBA and identify the sources of loadings. As BMPs to reduce loading of contaminants are developed for the activities that contribute to SBA loadings, the BMPs also should be applied in the SBA watershed.

2. Develop and implement management programs for Lake Del Valle, including possible control of swimming and boating.

   Increasing concerns have been raised regarding microbial pollution of source waters from recreational swimmers. It is recognized that, from a source water protection standpoint, the most desirable situation is to ban all whole-body contact in these source waters. Because SWP reservoirs are required to be multi-use facilities, it is not possible to ban swimming. Source water protection may be achieved by restricting swimming to areas bermed off from the main water body. For Lake Del Valle, a feasibility study is recommended to determine the need for, costs of, and institutional feasibility of creating and maintaining a bermed-off swimming area. If this is feasible, CALFED funding for implementation may be appropriate.

   Increasing concerns have been raised regarding microbial pollution of source waters from recreational swimmers.

   Additional microbial contaminant sources for Lake Del Valle include boating, other whole-body-contact activities, and sanitary waste handling facilities. Control of these sources may include education and limiting the locations of facilities and activities.

3. Develop and implement management programs for the upper Lake Del Valle watershed.

   Ranching operations in the Arroyo Valle watershed above Lake Del Valle appear to contribute nutrients that promote algal growth; livestock operations also may contribute pathogens to Lake Del Valle. A watershed management program, patterned after that initiated by the San Francisco Public Utility Commission for the Alameda Creek watershed above Calaveras Reservoir, is recommended. BMPs could be implemented as they are developed elsewhere.

Information Needed

1. Research and develop control strategies for algae in the SBA and Clifton Court Forebay.

   Algae can cause problems during drinking water treatment and can elicit T&O complaints from consumers. Copper sulfate and Komeen (a copper-based algicide) currently are being used to control the growth of algae in the SBA and Clifton Court Forebay. Although the use of copper products does not pose a public health threat, some municipalities are having difficulty meeting

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